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(54) **ELEVATOR LOAD WEIGHING SYSTEM**

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B66B 3/00 (2006.01)
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(58) **Field of Classification Search**
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(Continued)

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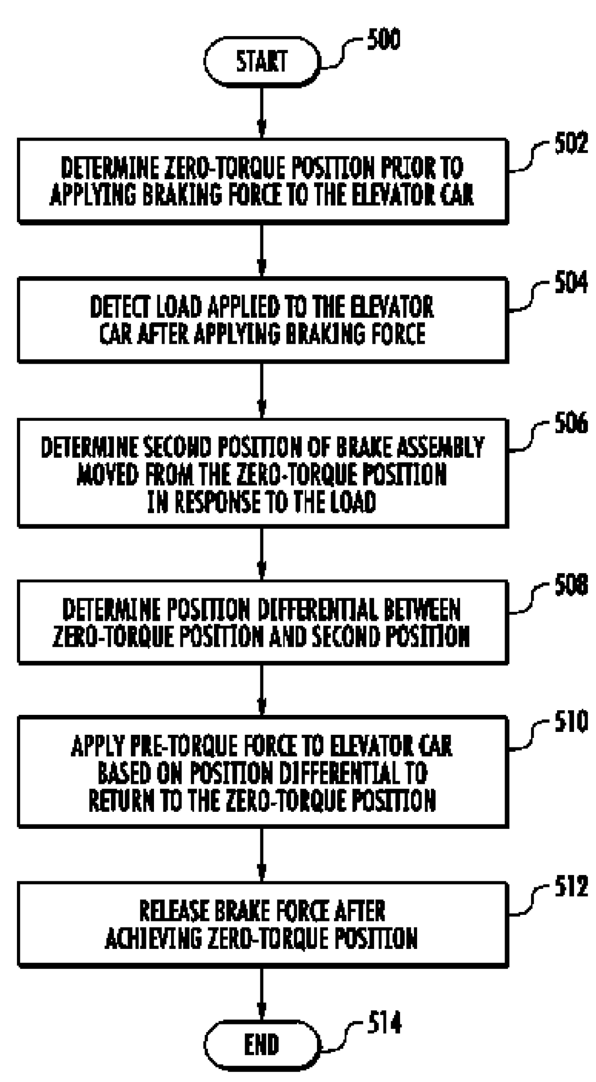
(57) **ABSTRACT**

An elevator load weighing system (**100**) includes a brake assembly (**104**) configured to apply a braking force that inhibits vertical movement of an elevator car (**106**), and rotate in response to realizing a torque applied thereto. A position monitoring mechanism (**112**) is coupled to the brake assembly (**104**) and is configured to output a position signal in response to a rotation of the brake assembly (**104**). An electronic elevator control module (**102**) is configured to determine a zero-torque position of the brake assembly (**104**) prior to engaging the brake assembly (**104**). The electronic elevator control module (**102**) is further configured to detect at least one rotational brake displacement of the brake assembly (**104**) based on the position signal.

15 Claims, 9 Drawing Sheets



(51) **Int. Cl.**
B66B 5/14 (2006.01)
G01G 19/52 (2006.01)
G01G 19/14 (2006.01)

(58) **Field of Classification Search**
USPC 187/393
See application file for complete search history.

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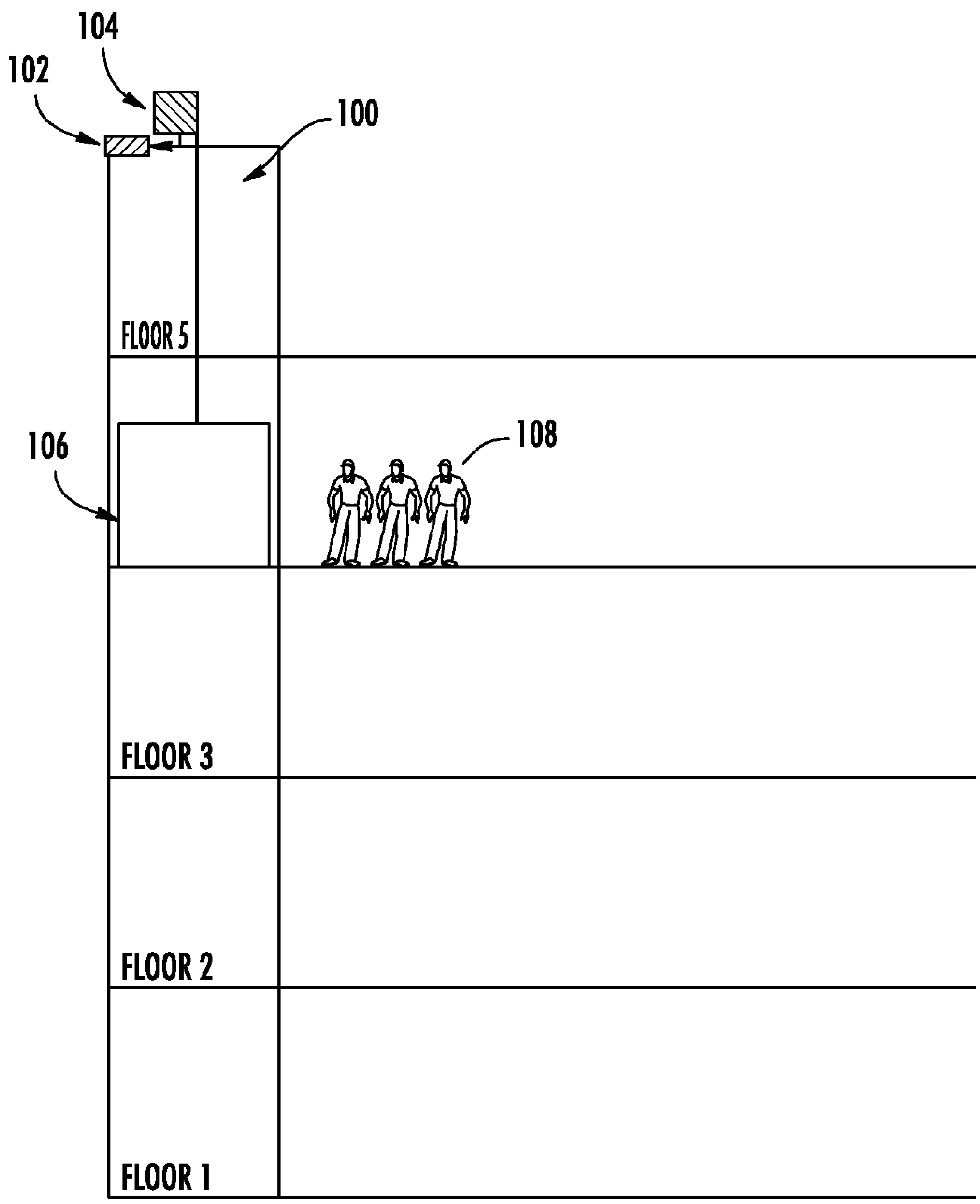

FIG. 1A

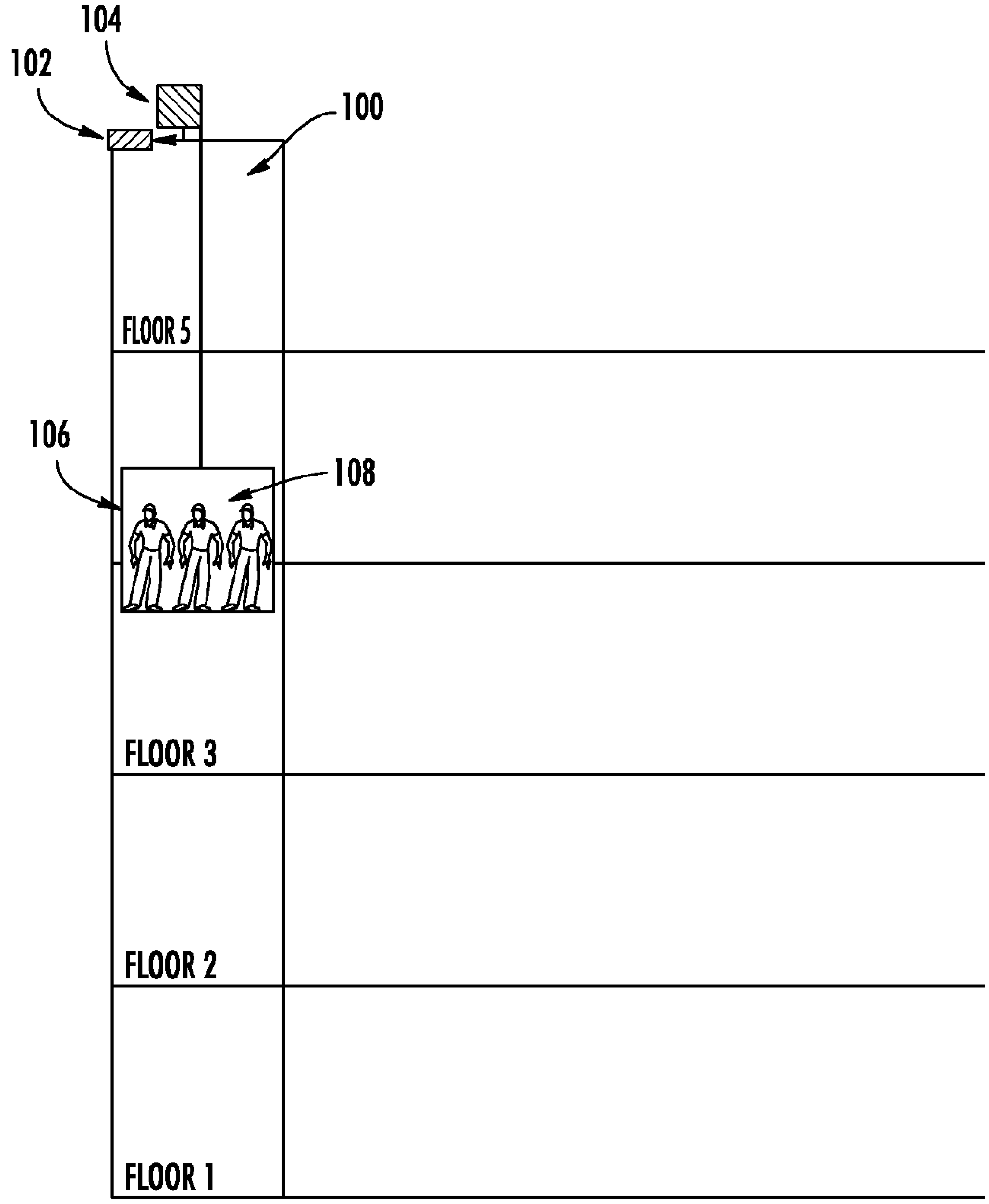

FIG. 1B

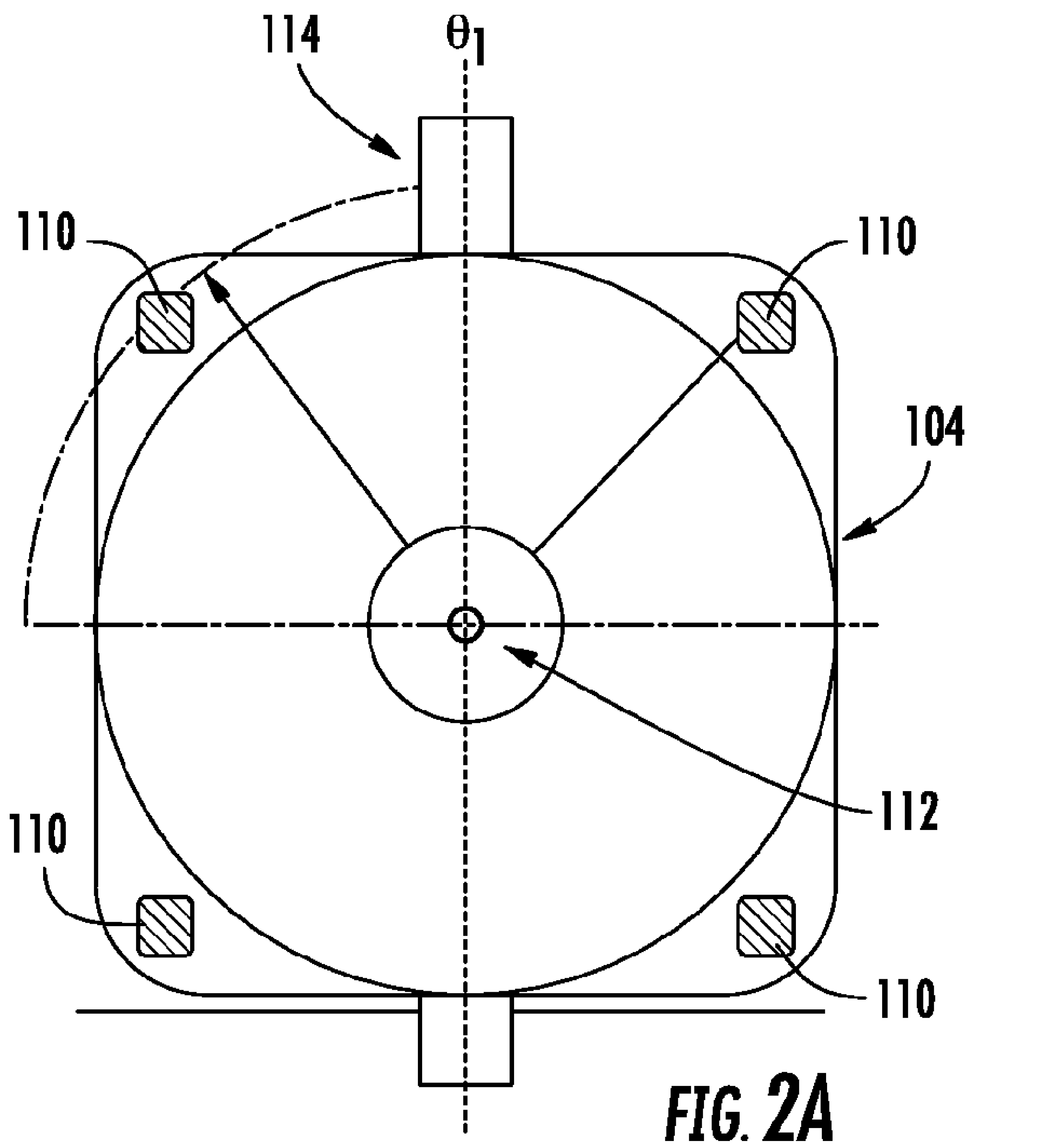

FIG. 2A

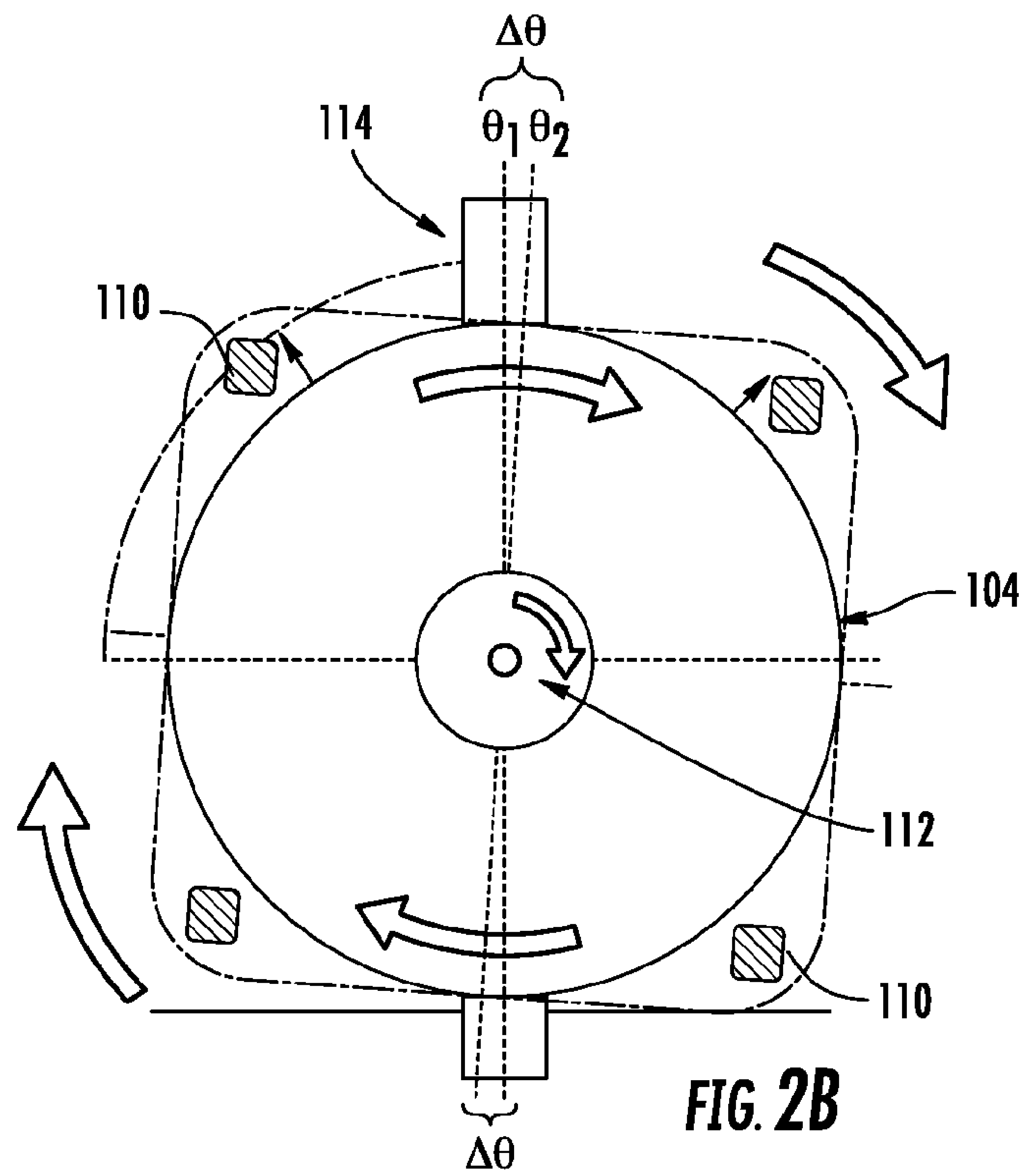

FIG. 2B

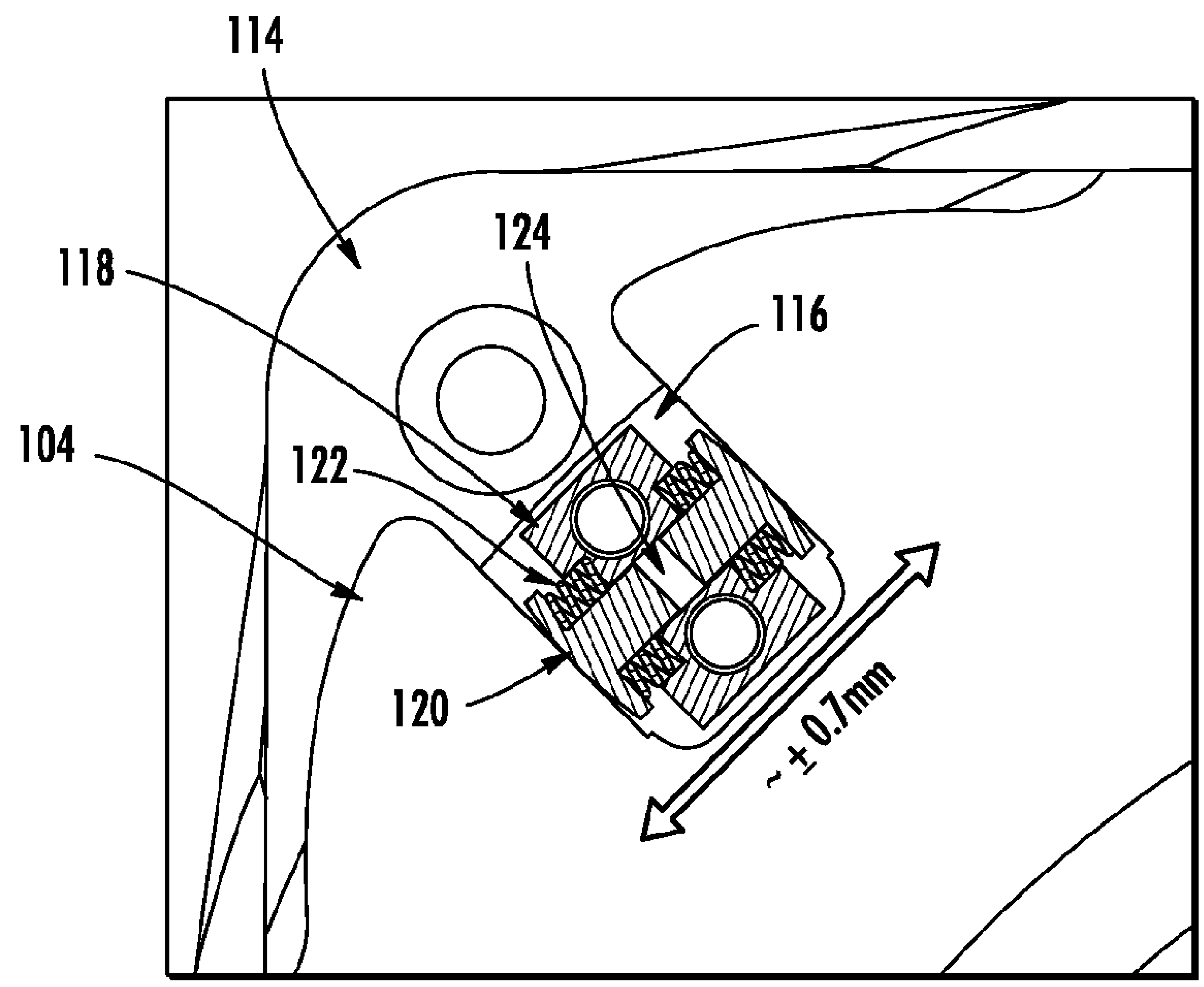

FIG. 3

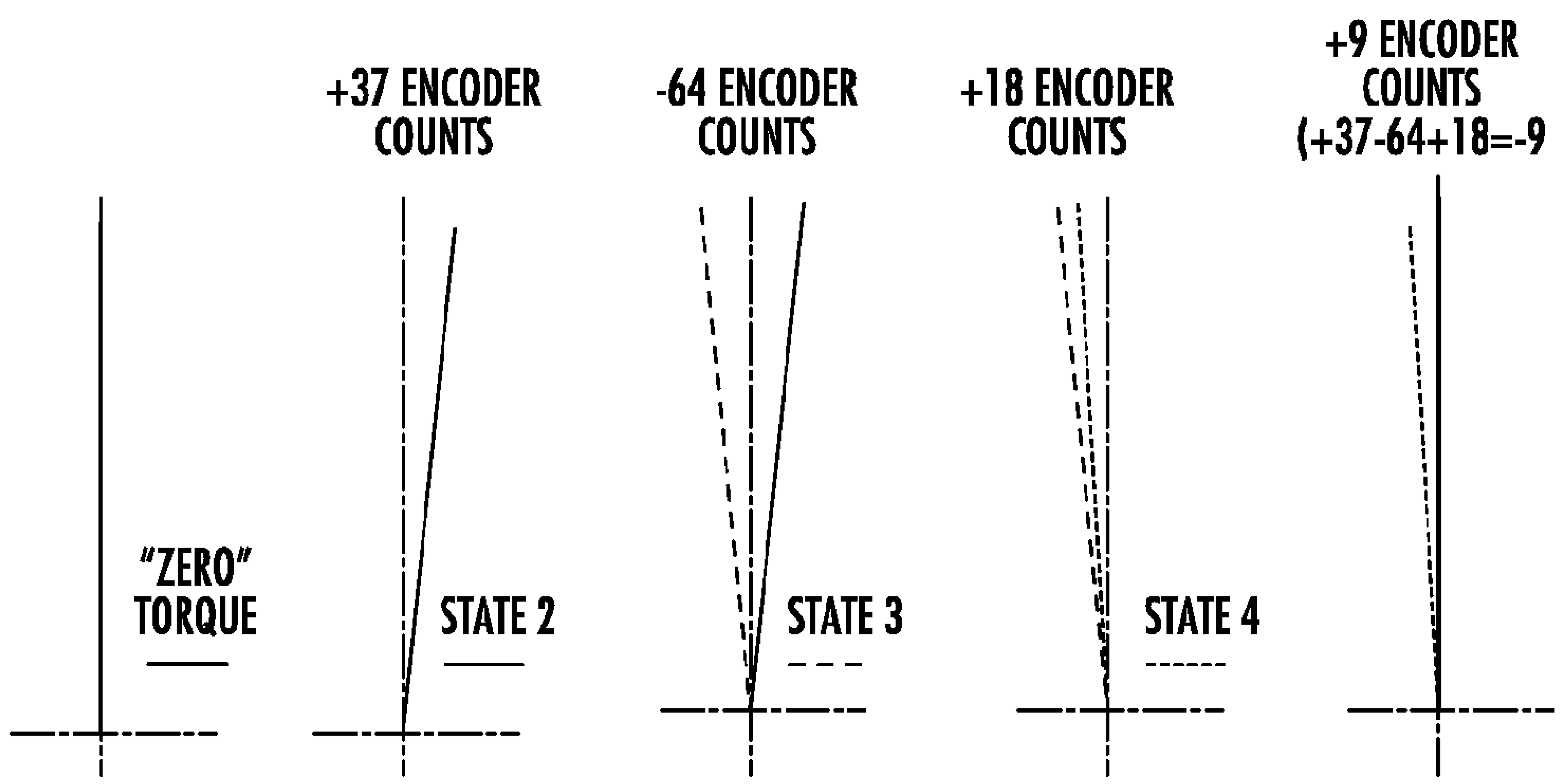

FIG. 4A FIG. 4B FIG. 4C FIG. 4D FIG. 4E

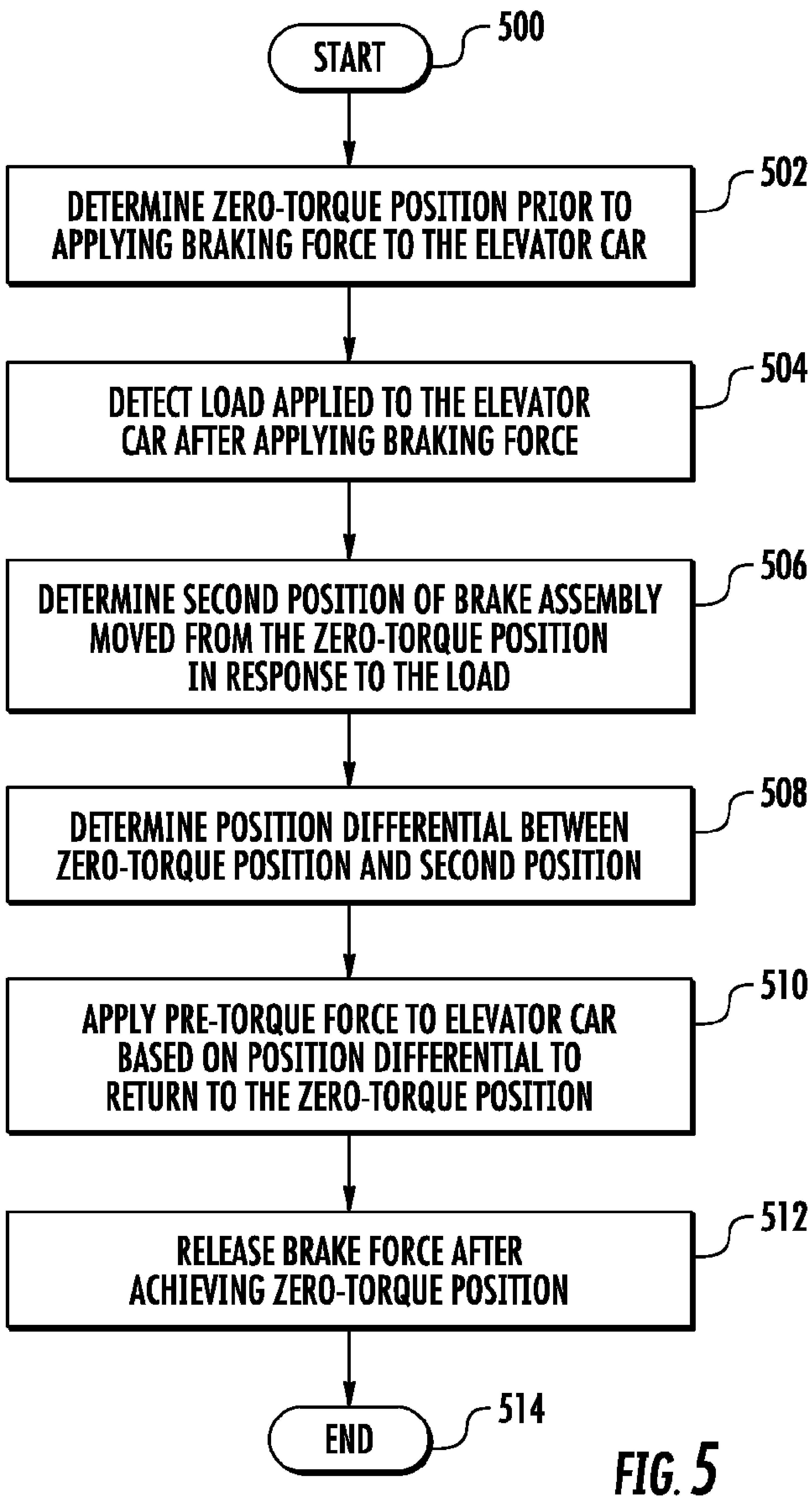
START
500
DETERMINE ZERO-TORQUE POSITION PRIOR TO APPLYING BRAKING FORCE TO THE ELEVATOR CAR
502
DETECT LOAD APPLIED TO THE ELEVATOR CAR AFTER APPLYING BRAKING FORCE
504
DETERMINE SECOND POSITION OF BRAKE ASSEMBLY MOVED FROM THE ZERO-TORQUE POSITION IN RESPONSE TO THE LOAD
506
DETERMINE POSITION DIFFERENTIAL BETWEEN ZERO-TORQUE POSITION AND SECOND POSITION
508
APPLY PRE-TORQUE FORCE TO ELEVATOR CAR BASED ON POSITION DIFFERENTIAL TO RETURN TO THE ZERO-TORQUE POSITION
510
RELEASE BRAKE FORCE AFTER ACHIEVING ZERO-TORQUE POSITION
512
END
514

FIG. 5

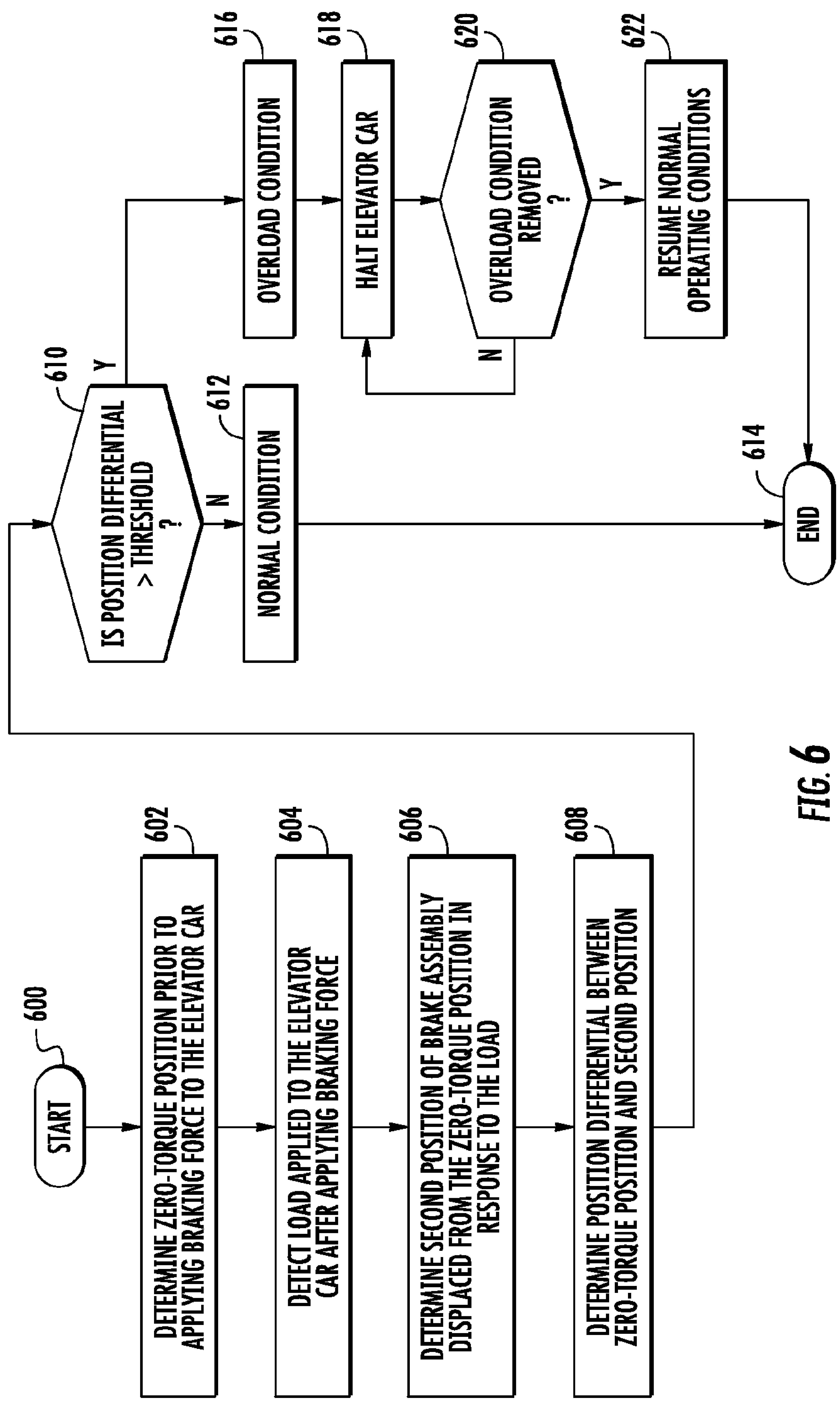
START
600
DETERMINE ZERO-TORQUE POSITION PRIOR TO APPLYING BRAKING FORCE TO THE ELEVATOR CAR
602
DETECT LOAD APPLIED TO THE ELEVATOR CAR AFTER APPLYING BRAKING FORCE
604
DETERMINE SECOND POSITION OF BRAKE ASSEMBLY DISPLACED FROM THE ZERO-TORQUE POSITION IN RESPONSE TO THE LOAD
606
DETERMINE POSITION DIFFERENTIAL BETWEEN ZERO-TORQUE POSITION AND SECOND POSITION
608
IS POSITION DIFFERENTIAL > THRESHOLD ?
610
Y
N
NORMAL CONDITION
612
OVERLOAD CONDITION
616
HALT ELEVATOR CAR
618
OVERLOAD CONDITION REMOVED ?
620
N
Y
RESUME NORMAL OPERATING CONDITIONS
622
END
614

FIG. 6

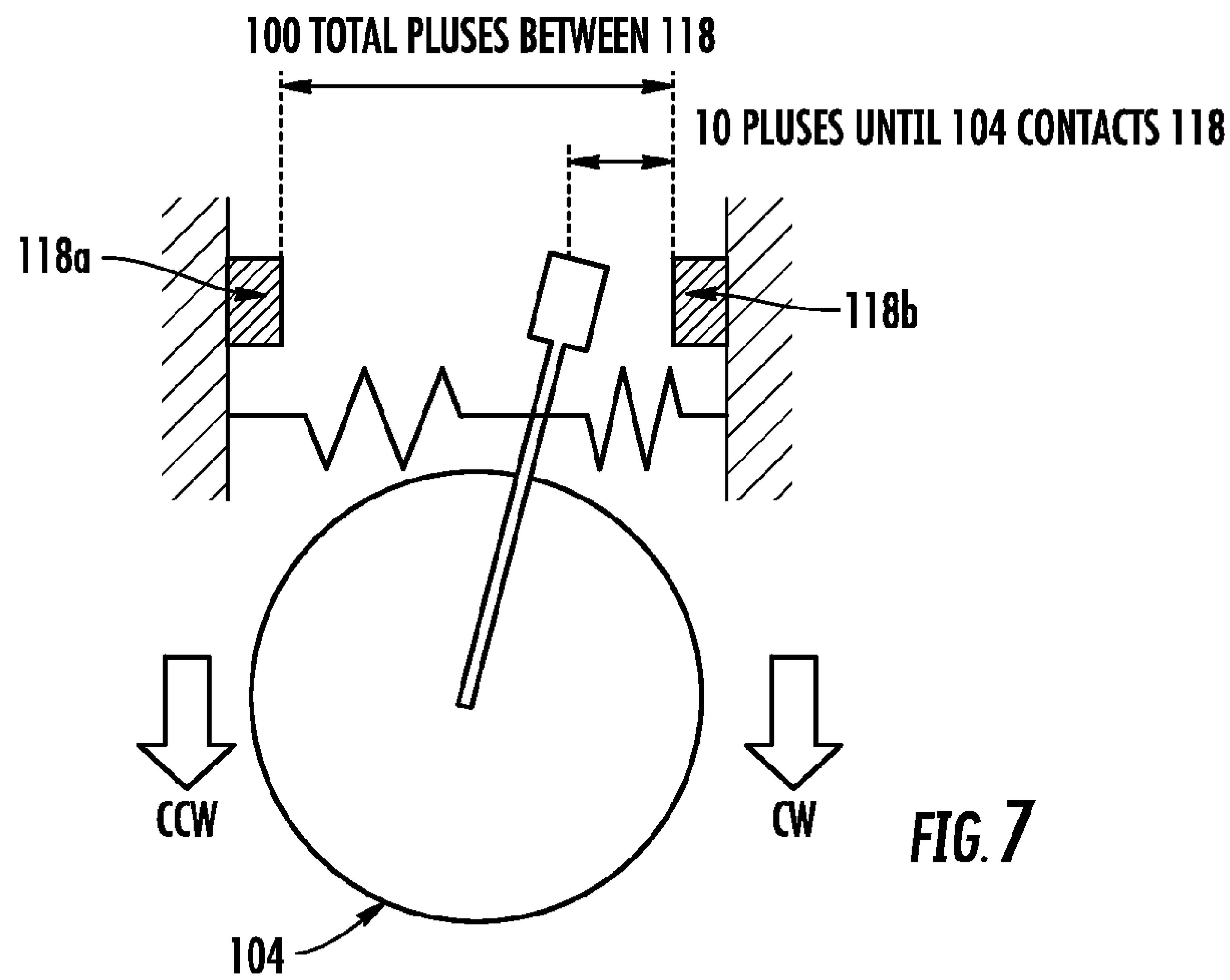
100 TOTAL PLUSES BETWEEN 118
10 PLUSES UNTIL 104 CONTACTS 118
118a
118b
CCW
CW
104

FIG. 7

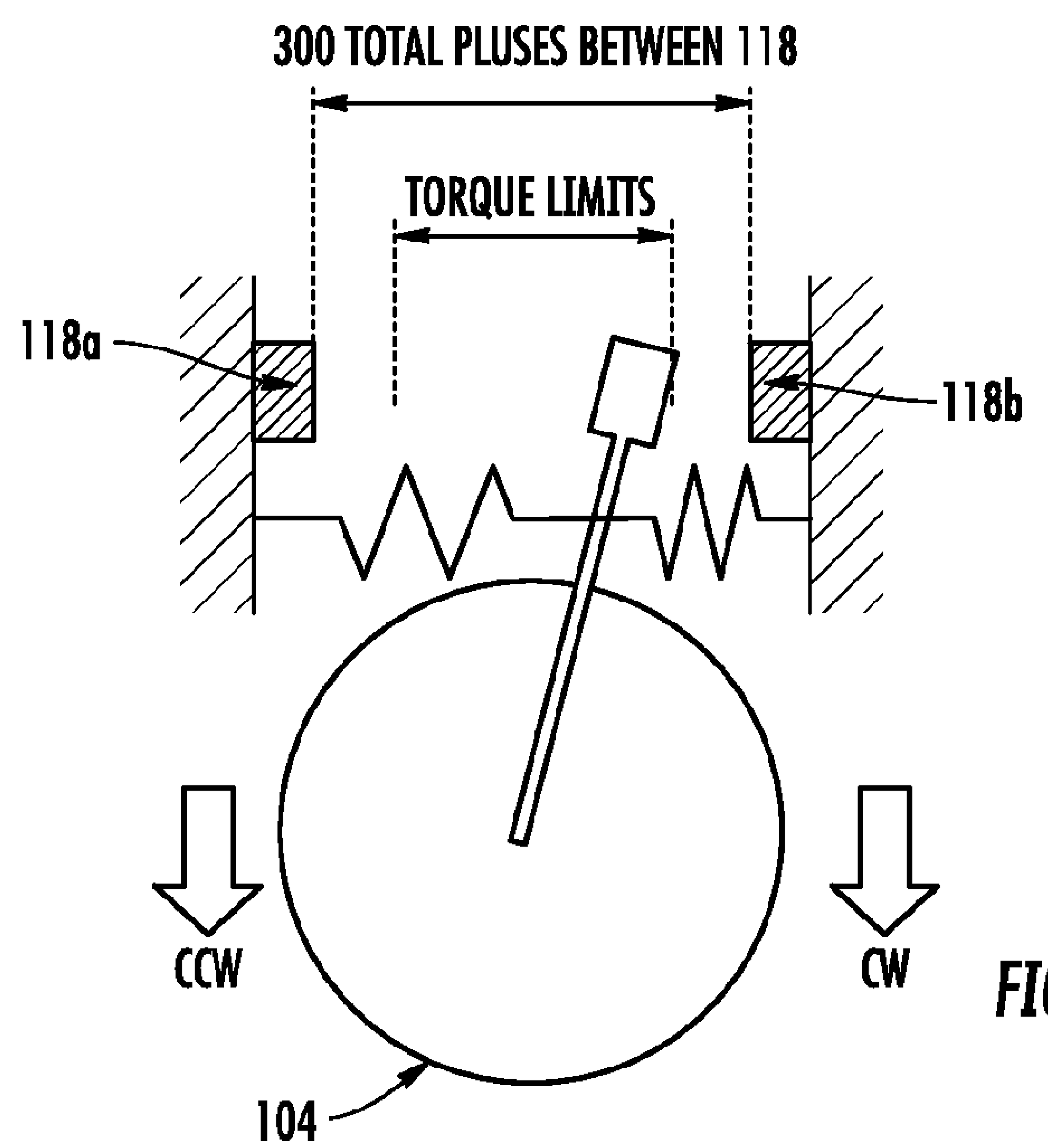
300 TOTAL PLUSES BETWEEN 118
TORQUE LIMITS
118a
118b
CCW
CW
104

FIG. 8

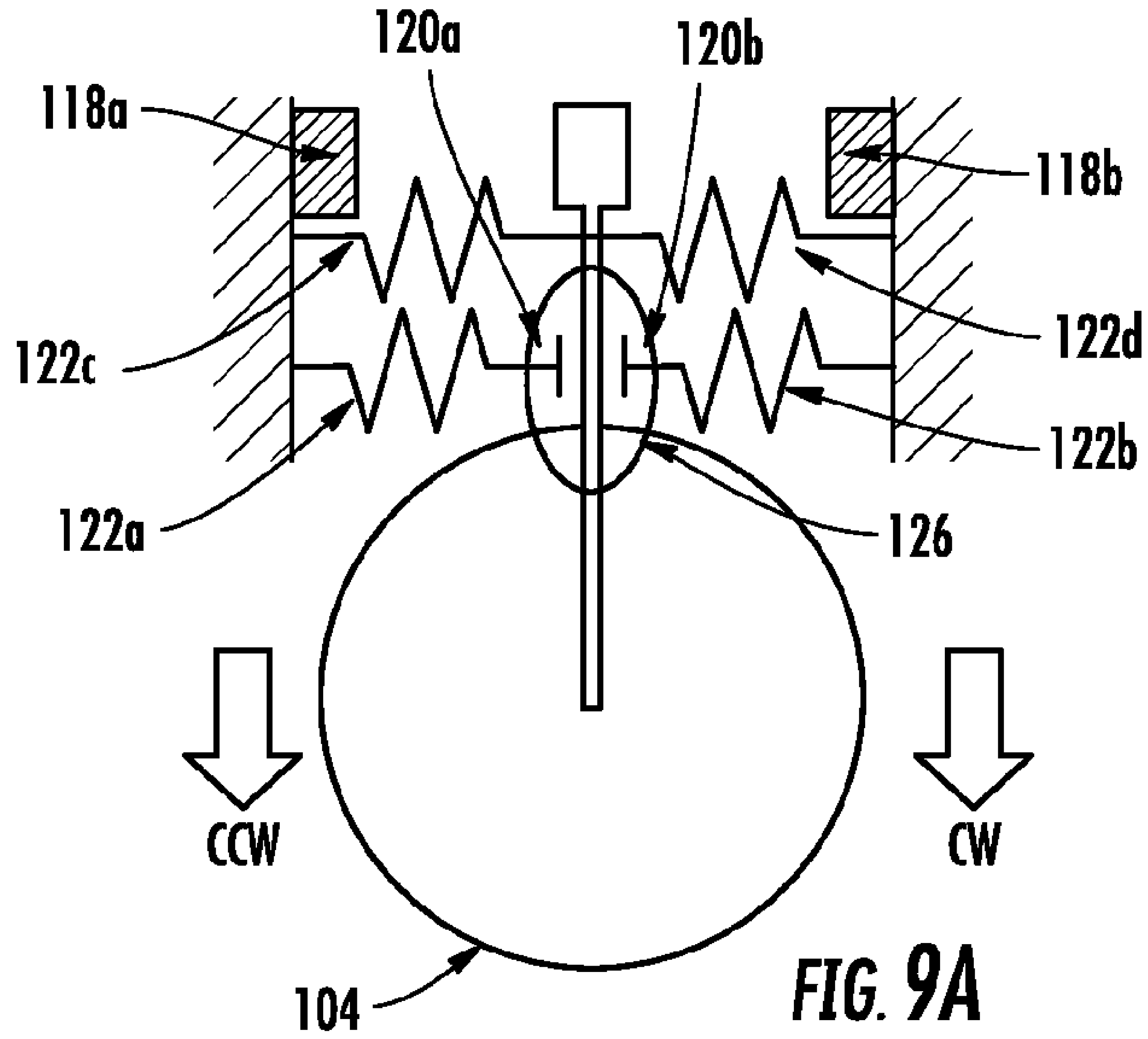
120a
120b
118a
118b
122c
122d
122b
122a
126
CCW
CW
104

FIG. 9A

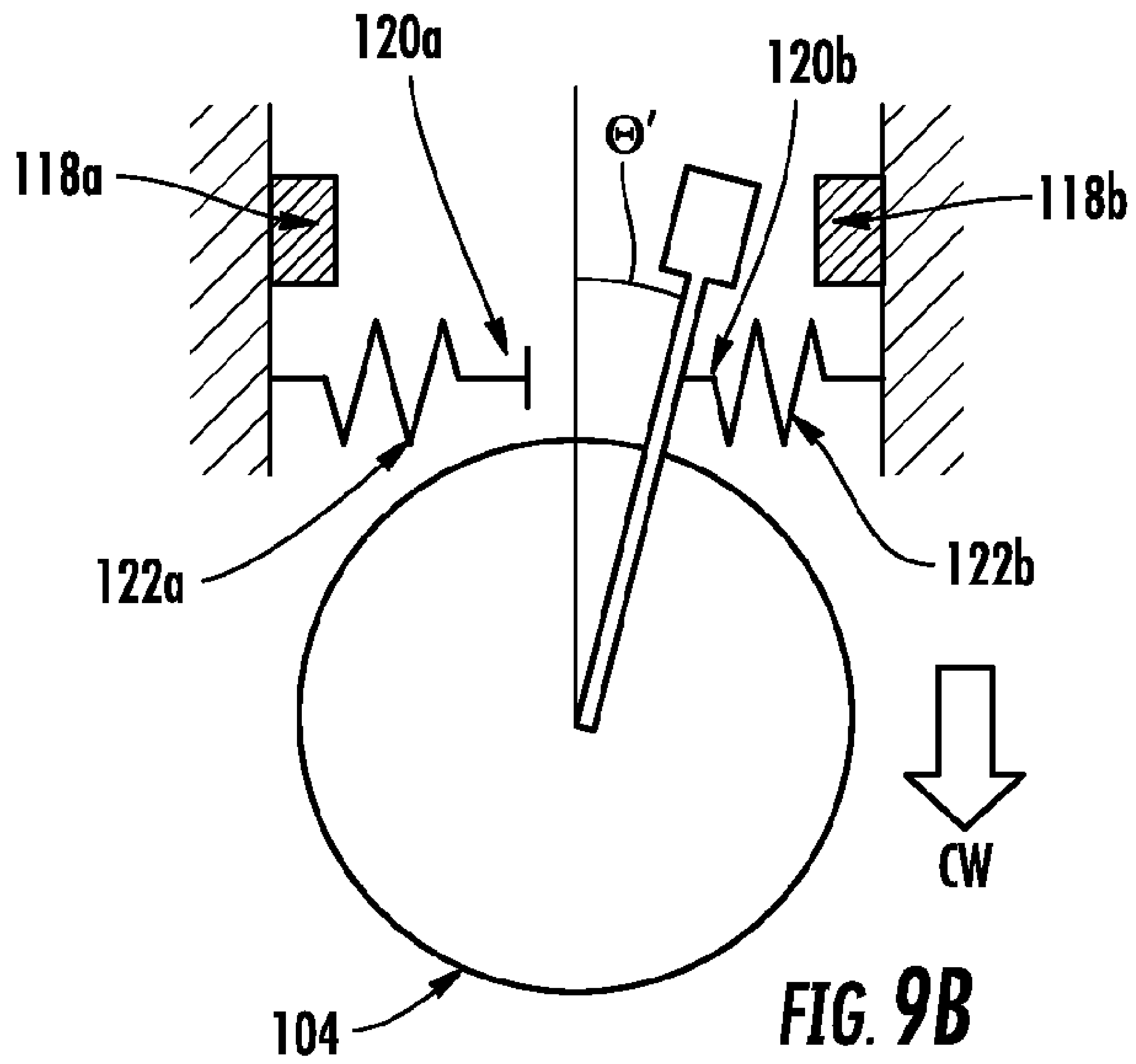
120a
120b
Θ'
118a
118b
122a
122b
CW
104

FIG. 9B

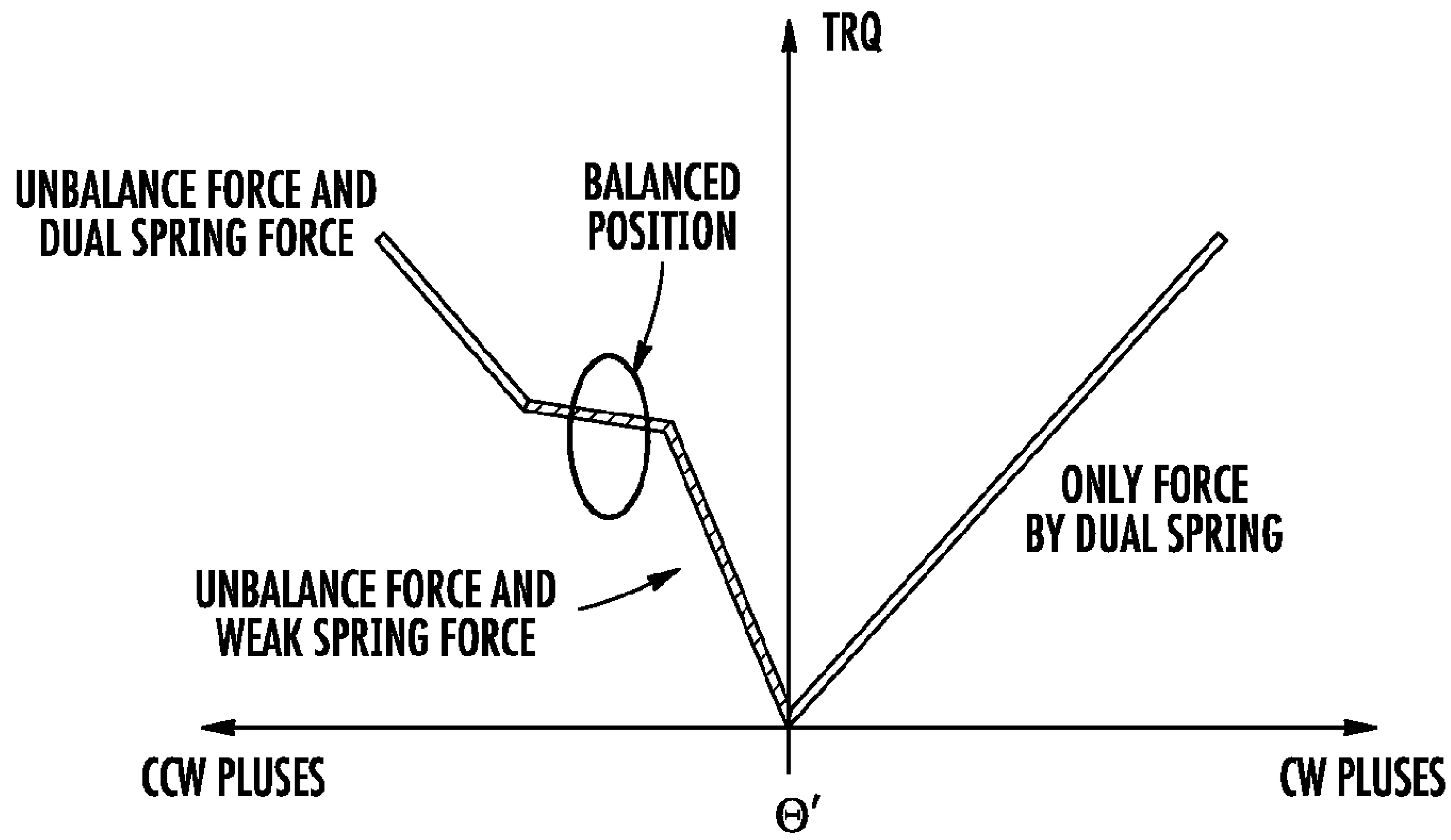
TRQ
UNBALANCE FORCE AND
DUAL SPRING FORCE
BALANCED
POSITION
ONLY FORCE
BY DUAL SPRING
UNBALANCE FORCE AND
WEAK SPRING FORCE
CCW PLUSES
Θ′
CW PLUSES

FIG. 9C

ELEVATOR LOAD WEIGHING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Stage Application of International Patent Application Serial No. PCT/US2015/049333, filed Sep. 10, 2015, which claims benefit to U.S. Provisional Application No. 62/049,533, filed Sep. 12, 2014, which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The present invention relates generally to elevator systems, and more particularly, to a load weighing system of an elevator system.

BACKGROUND

Elevator systems typically include a load weighing subsystem to provide information regarding a load applied to an elevator car. Conventional load weighing systems typically utilize load cells configured to directly detect a load applied to the elevator car. The load cells are disposed in a void between the elevator car and the hoistway frame. Recent elevator cars, however, have been designed as unibody cars which eliminate the void needed for disposing the load cells.

Alternatively, load cells can be coupled to the elevator car ropes to measure the rope tension. A change in the rope tension is then detected to determine when a load is applied to the elevator car. Friction realized by the elevator car ropes, however, can affect the measured tension and therefore vary the overall approximated detection and/or weight of the load.

SUMMARY

According to an embodiment, an elevator load weighing system includes a brake assembly configured to apply a braking force that inhibits vertical movement of an elevator car. The brake assembly is further configured to rotate in response to realizing a torque applied thereto. A position monitoring mechanism is coupled to the brake assembly and is configured to output a position signal in response to a rotation of the brake assembly. An electronic elevator control module is configured to determine a zero-torque position of the brake assembly prior to engaging the brake assembly. The electronic elevator control module is further configured to detect at least one rotational brake displacement of the brake assembly based on the position signal.

In addition to one or more of the features described above or below, further embodiments include:

a feature, wherein the elevator control module determines a load applied to the elevator car based on a plurality of brake displacements of the brake assembly, and determines an overload condition of the elevator car when the plurality of rotational brake displacements exceeds a threshold value;

a feature, wherein the position monitoring mechanism is coupled to the brake assembly and is configured to rotate among a plurality of rotational positions in response to a rotational displacement of the brake assembly, the position signal indicating at least one of an upward displacement or a downward displacement of the elevator car;

a feature, wherein the load is determined according to a rotational position differential between the zero-torque position and a second rotational position after engaging the brake assembly;

a feature, wherein the elevator control module detects a power loss of the elevator car and re-initializes the zero-torque position in response to detecting an initial rotational position output from the position monitoring mechanism after restoring power to the elevator car;

a feature, wherein a drive system controls the vertical displacement of the elevator car, and wherein the elevator control module commands the drive system to apply a pre-torque force on the brake assembly prior to disengaging the brake assembly, the pre-torque force returning the brake assembly to the zero-torque position;

a feature, wherein the pre-torque force is based on a sum of the rotational brake displacements; and

a feature, wherein the position monitoring mechanism is a rotary encoder, the brake assembly includes a disc spring units that elastically moves between a biased position corresponding to the zero-torque position, and wherein the rotational positions of the rotary detector have a linear relationship with respect to the torque and the pre-torque force.

In yet another embodiment, a method of determining a load of an elevator car comprises rotating a brake assembly configured to apply a braking force that inhibits the vertical movement of the elevator car. The brake assembly rotates in response to realizing a torque applied thereto. The method further includes outputting a position signal in response to rotating brake assembly. The method further includes determining a zero-torque position of the brake assembly prior to engaging the brake assembly and to detecting at least one rotational brake displacement of the brake assembly based on the position signal.

In addition to one or more of the features described above or below, further embodiments include:

a feature of determining a load applied to the elevator car based on a plurality of rotational brake displacements of the brake assembly, and determining an overload condition of the elevator car when the plurality of brake displacements exceeds a threshold value;

a feature of determining at least one of an upward displacement or a downward displacement of the elevator car based on at least one rotational brake displacement;

a feature of determining the load based on a rotational position differential between the zero-torque position and a second rotational position after engaging the brake assembly;

a feature of detecting a power loss of the elevator car and re-initializing the zero-torque position in response to detecting a first rotational brake displacement of the brake assembly after restoring power to the elevator car;

a feature of applying a pre-torque force on the brake assembly prior to disengaging the brake assembly, the pre-torque force returning the brake assembly to the zero-torque position; and

a feature of determining the pre-torque force based on a sum of the rotational brake displacements.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIGS. **1**A-**1**B illustrate a positional displacement of an elevator car in response to an added load according to an embodiment;

FIGS. **2A-2B** illustrate a brake assembly rotating between a zero-torque position and a second position in response to a torque induced by a positional displacement of an elevator car according to an embodiment;

FIG. **3** illustrates a rotation mechanism configured to allow a brake assembly to rotate with respect to a fixed portion of an elevator car according to an embodiment;

FIGS. **4A-4E** are linear expressions of a rotational displacement of a brake assembly according to an embodiment;

FIG. **5** is a flow diagram illustrating a method of returning an elevator car to a zero-torque position according to an embodiment;

FIG. **6** is a flow diagram illustrating a method of determining an overload condition of an elevator car according to an embodiment;

FIG. **7** illustrates a brake assembly according to another embodiment;

FIG. **8** illustrates a brake assembly according to still another embodiment; and

FIGS. **9A-9C** illustrate a brake assembly according to yet another embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIGS. **1A-1B**, an elevator load weighing system **100** is illustrated according to an embodiment. The elevator load weighing system **100** includes an electronic elevator control module **102**, and a brake assembly **104**. Brake assembly **104** may be part of a machine that imparts movement to elevator car **106**. The elevator control module **102** includes an electronic microcontroller, for example, configured to control the operation of the brake assembly **104** and the elevator car **106** as understood by one of ordinary skill in the art. The brake assembly **104** is selectively engaged to apply a braking force that inhibits vertical movement of an elevator car **106**. When engaged, the brake assembly **104** realizes a torque applied by the total weight of the elevator car **104**. The total weight of the elevator car includes, for example, the weight of an empty elevator car **106**, a counter weight coupled to the elevator car, and the weight of a load applied to the elevator car. The load includes, for example, passengers, or goods such as furniture, packages, etc.

The brake assembly **104** is configured to rotate when realizing a torque applied thereto. The torque is induced by in response to applying the braking force. A change in load realized by the elevator car **106** after applying the braking force can further increase the torque applied to the brake assembly **104**. As illustrated in FIG. **1A**, for example, an empty elevator car **106** is parked just after the brake assembly **104** is engaged. In this scenario, the only force applied to the brake assembly **104** is the weight of the empty elevator car **106**. It is appreciated by those of ordinary skill in the art that the elevator car **106** may include a counterbalance weight which may be factored into the total weight applied to the brake assembly **104**.

As illustrated in FIG. **1B**, the vertical position of the elevator car **106** is displaced as a load **108** is applied, which in this example includes passengers **108** boarding the elevator car **106**. In response to the added load **108**, the brake assembly **104** rotates with respect to a fixed reference point such as, for example, the frame of the elevator car **106**. The rotation of the brake assembly **104** is used to determine how the load **108** affects the vertical position of the elevator car **106** as discussed in greater detail below.

Turning now to FIGS. **2A-2B**, a brake assembly **104** is illustrated according to an embodiment. The brake assembly **104** includes one or more rotation mechanisms **110** and a position monitoring mechanism **112**. According to an embodiment, the rotation mechanisms **110** are coupled to the brake assembly **104** at respective housings located 90 degrees apart from one another. The rotation mechanisms **110** are configured to allow the brake assembly **104** to rotate with respect to a fixed point such as, for example, a bedplate supporting the elevator machine or housing of the brake assembly. The rotation mechanisms **110** may be formed as spring units, for example, as discussed in greater detail below. Although four rotation mechanisms **110** are illustrated, it is appreciated that more or less rotation mechanisms **110** may be used to allow rotation of the brake assembly **104**.

The position monitoring mechanism **112** is coupled to the brake assembly **102** and is configured to output a position signal in response to detecting a rotational displacement of the brake assembly **104**. According to an embodiment, the position monitoring mechanism **112** is a rotary encoder **112** configured to rotate among a plurality of rotational positions as understood by one of ordinary skill in the art. The rotary encoder **112** rotates along with the rotation of the brake assembly **104** and outputs the position signal (i.e., a pulse) in response to rotating from a first encoder position to a second encoder position. According to an embodiment, the rotary encoder **112** has 1024 positions per revolution (PPR). It is appreciated, however, that the rotary encoder **112** can range from 512 PPR to 4096 PPR. The position signal is output to the elevator control module **102**. The elevator control module **102** applies a directional operator (e.g., a positive direction or a negative direction) corresponding to each pulse output from the position monitoring mechanism **112**. The pulses indicated by each position signal indicates a displacement of the brake assembly **104** and ultimately indicates an upward movement or a downward movement of the elevator car **106** in response to a change in the load **108**.

Referring to FIG. **2A**, the brake assembly **104** is illustrated in a first position with respect to the elevator frame **114** (θ_1). The first position includes, for example, a zero-torque position occurring when the brake assembly **104** is disengaged (i.e., a braking force is not yet applied to the elevator car **106**). Turning to FIG. **2B**, the brake assembly **104** is rotated in a clockwise direction in response to realizing a torque. The torque can be applied to the brake assembly **104** when the elevator car realizes a load such as, for example, when the break assembly **104** is engaged. As discussed above, the torque realized by the brake assembly **104** can be varied as the load applied to elevator car **106** varies while the brake assembly **104** is engaged. In this manner, the brake assembly **104** rotates from the first position (θ_1) into a second position (θ_2). A position differential ($\Delta\theta$) is defined as the rotational difference between the first position (θ_1) and the second position (θ_2).

Referring to FIG. **3**, a rotation mechanism **110** is illustrated according to an embodiment. The rotation mechanism **110** is assembled as, for example, a disc spring unit **110** disposed in a respective spring well **116** formed in the brake assembly **104**. The disc spring unit **110** includes a spring housing **118**, a pair of moveable disc pistons **120**, and a pair of springs **122**. Each disc piston **120** includes a first end and a second end. The first end of each disc piston **120** is disposed in a bore **124** formed in the spring housing **118** and is configured to slide therein. The second end of each disc piston **120** extends from the bore **124** and contacts an inner wall of the spring well **116**. A spring **122** is interposed between the second end of the disc piston **120** and the spring housing **118**. Each spring **122** forces the second end of a respective disc piston **120** against the inner wall of the spring well **116**.

When a torque is applied to the brake assembly **104**, the brake assembly **104** is rotated in either a clockwise or counter-clockwise direction from a first position into a second position. In response to the brake assembly rotation, a first spring **122***a*, **122***b* is compressed allowing a respective disc piston **120** to side toward the spring housing **118**, while the second spring **122** extends allowing the respective disc piston **120** to slide away spring housing **118**. In this manner, the brake assembly **104** is allowed to rotate with respect to the elevator frame **114**. According to an embodiment, the brake assembly **104** can rotate, for example, approximately 0.7 millimeters (mm) in the clockwise or counterclockwise direction. When the torque is removed, the springs **122** return to their biased states such that brake assembly **104** returns to the first position (e.g., the zero-torque position).

The rotational positional displacement of the rotary encoder **112** can be expressed as a linear relationship with respect to the torque applied to the brake assembly **104** as illustrated in FIGS. **4**A-**4**E. Referring to FIG. **4**A, the brake assembly **104** is in a first state that exists prior to engaging the brake assembly **104**. Since the brake assembly **104** is not engaged, no torque is applied to the brake assembly **104**. The elevator car **106** can include an initial load or can be empty during this state prior to engaging the brake assembly **104**. According to an embodiment, the zero-torque position is measured when the elevator car **106** is stationary and level with a floor landing and the time period is, for example, approximately 1-3 seconds before the brake assembly **104** is engaged.

At FIG. **4**B, the brake assembly **104** is engaged at a second state such that the braking force is applied. After the brake assembly **104** is engaged, it is appreciated that the elevator car **106** can experience a slippage effect that displaces the elevator car **106** in a first direction with respect to the zero-torque position (e.g., forces the elevator downward from the zero-torque position). The elevator car slippage applies a torque on the brake assembly **104**, which in turn rotates the brake assembly **104** as discussed above. The rotary encoder **112** is rotated 37 positions in a clockwise direction, for example, as the brake assembly **104** rotates and outputs a plurality of position signal pulses indicating the 37 clockwise rotations of the rotary encoder **112**. The elevator control module **102** receives the position signals and stores a positive value (+37) in memory indicating the 37 clockwise rotations.

Turning to FIG. **4**C, the elevator car **106** realizes a reduction in load at a third state. The reduced load displaces the elevator car **106** in an opposite direction with respect to the zero-torque position (e.g., raises the elevator upward) and applies a torque on the brake assembly **104**, which in turn rotates the brake assembly **104** in the counterclockwise direction. Accordingly, the rotary encoder **112** is rotated 64 positions in the counterclockwise direction, for example, and outputs a plurality of position signal pulses indicating the 64 counterclockwise rotations of the rotary encoder **112**. The elevator control module **102** receives the position signals and stores a negative value (−64) in memory indicating the 64 counterclockwise rotations.

At FIG. **4**D, a new load is added to the elevator car **106** at a fourth state. The new load increases the weight of the elevator car **106** with respect to the weight of the elevator car **106** at the third state. The new load therefore displaces the elevator car **106** again in the first direction (e.g., forces the elevator downward) and applies a torque on the brake assembly **104**, which in turn rotates the brake assembly **104** again in the clockwise direction. The rotary encoder **112** is rotated 18 positions in the clockwise direction, for example, and outputs a plurality of position signal pulses indicating the 18 clockwise rotations of the rotary encoder **112**. The elevator control module **102** receives the position signals and stores a positive value (+18) in memory indicating the 18 clockwise rotations.

Turning to FIG. **4**E, the elevator control module **102** determines that the brake assembly **104** can be returned to the zero-torque position if the elevator car **106** is moved such that the brake assembly is displaced 9 clockwise rotations with respect to the fourth state. For example, the elevator control module **102** determines the net differential ($\Delta\theta$) of the position signal pulses (i.e., 37+(−64)+18=(−9)) to determine a displaced position of the brake assembly **104**. In the fourth state, for example, the brake assembly is displaced 9 counterclockwise rotational positions (−9) with respect to the zero-torque position of the first state illustrated in FIG. **4**A. The elevator control module **102** therefore determines that brake assembly **104** can be displaced 9 clockwise rotational positions (+9) to return the brake assembly **104** the zero-torque position (i.e., (−9)+9=0). According to an embodiment, the elevator control module **102** can command the elevator motor to output a pre-torque force that moves the elevator car upward, thereby displacing the brake assembly 9 clockwise rotational positions. Once the brake assembly **104** is returned to the zero-torque position, the brake assembly **104** can be disengaged and the elevator car **106** can be dispatched with a reduction in jerk.

According to an embodiment, the elevator control module **102** can determine an overload condition of the elevator car **106**. More specifically, the elevator control module **102** sets a rotational position differential threshold ($\Delta\theta_{TH}$). The rotational position differential threshold $\Delta\theta_{TH}$ corresponds, for example, to approximately 105% duty load of the elevator car **106**. The elevator control module **102** then compares $\Delta\theta$ to $\Delta\theta_{TH}$. When $\Delta\theta$ exceeds $\Delta\theta_{TH}$ (e.g., 105% duty load), the elevator control module **102** determines an overload condition of the elevator car **106**. In response to the overload condition, the elevator control module **102** can halt operation of the elevator car **106** and output one or more alerts including, but not limited to, a sound alert, and a display alert. In this manner, an overload condition may be determined while the elevator doors are open and without re-leveling the elevator car **106**. When the overload condition is removed (e.g., 85% duty load of the elevator car **104** or less is determined) the elevator control module **102** can resume operation of the elevator car **106**.

According to another embodiment, the elevator control module **102** performs an initialization and rise compensation operation to compensate for weight imbalances realized by the elevator car **106** as the elevator car **106** travels from the lowest building floor to the highest building floor. More specifically, an empty elevator car **106** is run from the lowest building floor landing to the following floor landing and back. The elevator control module **102** determines a number of pulses output from the rotary encoder **112** based on an empty car and a zero-torque position at the bottom floor landing. A first rotational position differential threshold ($\Delta\theta_{TH\_1}$) is then set which corresponds to an overweight condition at the bottom floor landing.

The empty elevator car **106** is then run to the highest building floor and the elevator control module **102** determines a number of pulses output from the rotary encoder **112** based on an empty car and a zero-torque position at the top floor landing. A second rotational position differential threshold ($\Delta\theta_{TH\_2}$) is then set which corresponds to an overweight condition at the highest floor landing. The elevator control module **102** can then determine how the rope weight vs. rise affects the elevator car based on a comparison between the $\Delta\theta_{TH\_1}$ and $\Delta\theta_{TH\_2}$.

According to another embodiment, the elevator control module **102** performs a power loss re-initialization operation after realizing loss of power to the elevator car **106**. More specifically, the elevator control module **102** detects an abnormal event such as, for example, a power outage. When power is restored to the elevator car **106**, the elevator control module **102** confirms that the elevator car doors are closed and is capable of automatically re-calibrating the zero-torque position of the brake assembly **104**. In a first scenario, the elevator control module **102** retrieves the zero-torque position previously stored in memory and controls the elevator motor to adjust the position of the elevator car **106** and gradually achieve the zero-torque position.

According to a second scenario, the elevator control module **102** assumes that the elevator car **106** experienced a slippage effect during the abnormal event. Based on this assumption, the elevator control module **102** controls the elevator motor to gradually raise the elevator car **106** until one or more position signal pulses are received from the rotary encoder **112**. Once the position signal pulses are received, the elevator control module **102** determines that the brake assembly **104** is returned to approximately the zero-torque position and the brake assembly **104** is disengaged. In this manner, abrupt jerking of the elevator car **106** following an emergency stop event may be reduced.

Referring now to FIG. **5**, a flow diagram illustrates a method of returning an elevator car to a zero-torque position according to an embodiment. The method begins at operation **500**, and at operation **502** a zero-torque position of a brake assembly is determined prior to applying a braking force to the elevator car. At operation **504**, a load applied to the elevator car is detected after applying the braking force. At operation **506**, a second position of the brake assembly is determined. According to an embodiment, the second position is a displaced rotational position of a brake assembly with respect to the zero-torque position induced by the applied load. At operation **508**, a position differential between the second position and the zero-torque position is determined. At operation **510**, a pre-torque force is determined based on the position differential, and the pre-torque force is applied the braking assembly to return to the pre-torque position. At operation **512**, the braking force is removed from the elevator car and the method ends at operation **514**.

Turning now to FIG. **6**, a flow diagram illustrates a method of determining an overload condition of an elevator car according to an embodiment. The method begins at operation **600**, and at and at operation **602** a zero-torque position of a brake assembly is determined prior to applying a braking force to the elevator car. At operation **604**, a load applied to the elevator car is detected after applying the braking force. At operation **606**, a second position of the brake assembly is determined. According to an embodiment, the second position is a displaced rotational position of a brake assembly with respect to the zero-torque position induced by the applied load. At operation **608**, a position differential between the second position and the zero-torque position is determined. At operation **610**, the position differential is compared to a position differential threshold. When the position differential does not exceed the threshold, a normal condition is determined at operation **612** and the method ends at operation **614**. The normal condition allows an elevator car to continue operating as normal without interruption. When, however, the position differential exceeds the threshold, an overload condition is determined at operation **616**, and the elevator car is halted at operation **618**. At operation **620**, a determination is made as to whether the overload condition is removed. If the overload condition is not removed, the elevator car remains halted at operation **618**. When, however, the overload condition is removed, the elevator car is returned to normal operating conditions at operation **622** and the method ends at operation **614**.

Turning now to FIG. **7**, a rotation mechanism **110** is illustrated according to another embodiment. The spring housing **118** is shown to have a first sidewall **118*a*** and an opposing second sidewall **118*b***. The total number of pulses for the brake assembly **104** to rotate between the opposing sidewalls **118*a*-118*b*** is predetermined. For example, the total number of pulses for the brake assembly **104** to rotate between the opposing sidewalls **118*a*-118*b*** is 100 pulses. When the brake is engaged, a driving torque is applied to the brake assembly **104**, which rotates the brake assembly **104** in a clockwise example, for example. The number of pulses (i.e., contact pulses) in response to rotating the brake assembly **104** is counted until the brake assembly **104** abuts against the second sidewall **118*b***. In this case, for example, 10 pulses are counted until the brake assembly **104** contacts the second sidewall **118*b***. A balanced pulse count can be determined using the following equation:

$$P_B=(P_T/n)-P_C, \text{ where}$$

P_B=the balanced pulse count;

P_T=the total pulse count;

n=the number of brake assembly sidewalls; and

P_C=the number of contact pulses

In the case described above, the balanced pulse count is determined as follows:

$$P_B=(100/2)-10, \text{ where } P_B \text{ is calculated to be 40}$$

Accordingly, a pre-torque force can be applied to rotate the brake assembly **104** according to the balanced pulse count, i.e., 40 pulses, in a clockwise direction from the first sidewall **118*a***. In this manner, the brake assembly **104** is determined to be balanced and the brake assembly can be disengaged.

According to another embodiment, a servo-lock initialization feature can be used to determine a pre-torque force. More specifically, during initialization and prior to lifting the brake, no pulses are counted and there is no estimation of the pre-torque. When the brake is lifted during initialization, the elevator control module **102** controls the elevator motor to maintain zero speed with respect to a calculated pre-torque. The elevator control module **102** further includes a position feedback control loop circuit that determines a displacement of the elevator car after the brake is lifted. When the brake is lifted, the elevator control module **102** controls the elevator motor to maintain the position of the car thereby initiating a servo-lock mode. The elevator control module **102** analyzes the gain signal provided by the position feedback control loop circuit. A high gain indicates a high position loop gain in position feedback loop. As the gain changes from high gain to low gain, the pulses of the encoder are counted indicating displacement of the elevator car. Based on the counted pulses, the pre-torque force is determined as discussed above.

Turning now to FIG. **8**, a rotation mechanism **110** is illustrated according to another embodiment. In this case, a first torque limit and a second torque exist in the system.

With the brake engaged, a drive torque is applied to the brake assembly **104** to rotate the brake assembly **104** toward the first torque limit (e.g., a direction of 100% applied torque). A first number of limit pulses (P_{L1}) (e.g., 70 pulses) are counted until the brake assembly reaches the first torque limit. An opposing drive torque is then applied to rotate the brake assembly **104** toward the second torque limit (e.g. a direction of 0% torque). A second number of limit pulses (P_{L2}) are counted until the brake assembly reaches the second torque limit (e.g., 130 pulses). Accordingly, a total of 200 pulses is determined between the first and second torque limits. A balanced pulse count can be determined using the following equation:

$$P_B=(P_{L2}-P_{L1})/n, \text{ where}$$

P_B=the balanced pulse count;
P_{L1}=the first number of limit pulses;
P_{L2}=the second number of limit pulses; and
n=the number of brake assembly sidewalls.

In the case described above, the balanced pulse count is determined as follows:

$$P_B=(130-70)/2, \text{ where } P_B \text{ is calculated to be } 30$$

Accordingly, a pre-torque force can be applied to rotate the brake assembly **104** according to the balanced pulse count. In this manner, the brake assembly **104** is determined to be balanced and the brake assembly can be disengaged.

Turning now to FIGS. **9**A-**9**C, a rotation mechanism **110** is illustrated according to another embodiment. When the brake assembly **104** is balanced, the disc pistons **120** are in a neutral position and a gap **126** exists in the bore **124** (see FIG. **9***a*). As the brake assembly is rotated a distance (θ') with respect to the neutral position, an elastic force is applied by the springs **122***a*-**122***b* on a respective disc piston **120**. According to an embodiment, an additional set of springs **122***c*-**122***d* can be included to provide a dual-spring force (see FIG. **9**B). The applied elastic force can be determined using, for example, a sensor coupled to the respective spring **122***a*-**122***b*. When the brake is engaged and torque is applied such that the brake assembly **104** is rotated in a first direction (e.g., a clockwise direction), the brake assembly **104** is driven to rotate in an opposing second direction (e.g., the counter-clockwise direction) until no elastic force is applied disc pistons **120**. As shown in FIG. **9**C, a neutral position can be determined when the elastic force reaches a plateau (i.e., is flat). Accordingly, it is determined the brake assembly **104** has been returned to the neutral position and the brake assembly **104** is balanced.

According to another embodiment, the total number of pulses can be determined following initial contact of the brake assembly **104** against a sidewall **118***a*, **118***b*. For example, once the brake assembly **104** rotates in a clockwise direction and abuts the sidewall **118***b* after the brake is engaged and the number of contact pulses are determined, the brake assembly **104** can be rotated in an opposite direction (i.e., counterclockwise). The number of pulses are then counted until the brake assembly **104** contacts the opposing sidewall **118***a*. Thus, the total number of pulses between the opposing sidewalls **118***a*-**118***b* are determined.

As used herein, the term module refers to processing circuitry that may include an application specific integrated circuit (ASIC), an electronic circuit, an electronic processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

While the invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

The invention claimed is:

1. An elevator load weighing system, comprising:
- a brake assembly configured to apply a braking force that inhibits vertical movement of an elevator car, the brake assembly configured to rotate in response to realizing a torque applied thereto;
- a position monitoring mechanism coupled to the brake assembly and configured to output a position signal in response to a rotation of the brake assembly; and
- an electronic elevator control module in electrical communication with the position monitoring mechanism, the elevator control module configured to determine a zero-torque position of the brake assembly prior to engaging the brake assembly and to detect at least one rotational brake displacement of the brake assembly based on the position signal.

2. The elevator load weighing system of claim **1**, wherein the elevator control module determines a load applied to the elevator car based on a plurality of brake displacements of the brake assembly, and determines an overload condition of the elevator car when the plurality of rotational brake displacements exceeds a threshold value.

3. The elevator load weighing system of claim **2**, wherein the position monitoring mechanism is coupled to the brake assembly and is configured to rotate among a plurality of rotational positions in response to a rotational displacement of the brake assembly, the position signal indicating at least one of an upward displacement or a downward displacement of the elevator car.

4. The elevator load weighing system of claim **3**, wherein the load is determined according to a rotational position differential between the zero-torque position and a second rotational position after engaging the brake assembly.

5. The elevator load weighing system of claim **4**, wherein the elevator control module detects a power loss of the elevator car and re-initializes the zero-torque position in response to detecting an initial rotational position output from the position monitoring mechanism after restoring power to the elevator car.

6. The elevator load weighing system of claim **3**, further comprising:
- a drive system that controls the vertical displacement of the elevator car, wherein the elevator control module commands the drive system to apply a pre-torque force on the brake assembly prior to disengaging the brake assembly, the pre-torque force returning the brake assembly to the zero-torque position.

7. The elevator load weighing system of claim **6**, wherein the pre-torque force is based on a sum of the rotational brake displacements.

8. The elevator load weighing system of claim **3**, wherein the position monitoring mechanism is a rotary encoder, the brake assembly includes a disc spring unit that elastically moves between a biased position corresponding to the zero-torque position and a displaced position corresponding to a rotational position that is displaced with respect to the zero-torque position, and wherein the rotational positions of the rotary encoder have a linear relationship with respect to the torque and the pre-torque force.

9. A method of determining a load of an elevator car, the method comprising:

rotating a brake assembly configured to apply a braking force that inhibits the vertical movement of the elevator car, the brake assembly rotating in response to realizing a torque applied thereto;

outputting a position signal in response to rotating brake assembly; and

determining a zero-torque position of the brake assembly prior to engaging the brake assembly and to detecting at least one rotational brake displacement of the brake assembly based on the position signal.

10. The method of claim **9**, further comprising determining a load applied to the elevator car based on a plurality of rotational brake displacements of the brake assembly, and determining an overload condition of the elevator car when the plurality of brake displacements exceeds a threshold value.

11. The method of claim **10**, further comprising determining at least one of an upward displacement or a downward displacement of the elevator car based on at least one rotational brake displacement.

12. The method of claim **11**, further comprising determining the load based on a rotational position differential between the zero-torque position and a second rotational position after engaging the brake assembly.

13. The method of claim **12**, further comprising detecting a power loss of the elevator car and re-initializing the zero-torque position in response to detecting a first rotational brake displacement of the brake assembly after restoring power to the elevator car.

14. The method of claim **13**, further comprising:

applying a pre-torque force on the brake assembly prior to disengaging the brake assembly, the pre-torque force returning the brake assembly to the zero-torque position.

15. The method of claim **14**, further comprising determining the pre-torque force based on a sum of the rotational brake displacements.

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